Modelling of Nearshore Wave, Current and IG-Wave Motion

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LONG-TERM GOAL

The long-term goal is to develop accurate and efficient models for the dynamics of nearshore processes. The model development is to be done in such a way as to render the completed model useful in operational contexts. This will involve the use of data assimilation in order to enhance the accuracy of forecasts.

OBJECTIVES

The present work is contributing to the long-term goal by testing and further developing the capabilities of the SHORECIRC circulation model system. This includes work on three different groups of tasks

- Model Testing and Verifications.
- Model Developments and Analysis
- Application Oriented Developments

Each of those are in one way or the other oriented toward bringing the SHORECIRC (SC) model on a form where it can be used on a more routine basis by other users, including Naval operations planners.

APPROACH

This project is a collaborative effort between the Center for Applied Coastal Research (CACR), University of Delaware, and The Naval Research Laboratory (NRL), Stennis, Mississippi with Dr. Kaihatu (COPI) and his group.

WORK COMPLETED

Reference Version of the Model System. Work on development of a reference version for the model was a top priority for the project. This work has essentially been completed, and a manual that describes this version has been written.

The work has included a serious overhaul of the computer code to remove older, now abundant model components, fine tune details of input and output etc. In order to facilitate other user's implementation of the model we also developed a bench mark example for testing the correct function of the model.

The reference version of the model system and the manual is being made available to the NOPP group of PI's for testing and commenting, and was presented to the group at a recent meeting in Monterey, CA. Eventually the manual will be sent out as a Center for Applied Coastal Research (CACR) research report, and the model will be made available to registered users. Work to establish the arrangements for this will be undertaken in due course.

Analysis of instability for wave current interaction. In the process of the work with the reference version we discovered, that under certain conditions with wave current interaction active in the computations, the model developed a peculiar and very non-physical current pattern with stationary vortices that grew very slowly in time, but did not propagate, even with a strong longshore current. After extensive analyses that explicitly identified the origins of the problem it was eventually removed. This effort was assisted by intellectual support also from researchers funded by the Sea Grant project on Rip currents and the NOPP project.

Expansion of the SC-model to deeper water. The short wave forcing of the SC-model has been extended to intermediate water depth. The equivalent analytical expressions for the current profiles and the most important quasi-3D coefficients have also been determined. The results show what is needed to extend the model validity to deeper water for comparison with the POM model, and how far out the existing model is accurate.

The results also show the effects that depth varying wave forcing have on the offshore velocity profiles in rip currents which are being studied in the Sea Grant project.

Effect of Errors in the Cross-shore Boundary Conditions. One of the major problems in ocean modelling is that information generally is not available for a correct specification of the model boundary conditions.

We have studied how such errors change the flow inside the computational domain for a characteristic case of a long straight beach. This has been done numerically by running experiments with the SC-model for both the correct and the erroneous boundary condition, and it has been done analytically. The analytical solution is based on a perturbation expansion, which assumes reasonably small errors.

Comparison of SC with laboratory data. Comparisons have been conducted with the detailed and accurate measurements from the Large scale Sediment Transport Facility (LSTF) at WES become available. These are for a simpler case with a long straight beach, but initial comparisons showed interesting results. While the longshore currents were quite well reproduced deviations were significant in the predictions of the cross-shore circulation. This has lead to a renewed realization of the need for creating an alternative wave driver for the circulation computations. Further comparisons are planned.

This work is under preparation for publication (Qin et al, 2000)

Comparison with NSSM and other Navy models. We have performed comparisons of the SC model against a wave-forced ADCIRC model (under development at NRL). Tests have been primarily done on simple configurations (plane beach, barred beach, h(x) only). These tests indicate that the SC model, in general, evidences more mixing than the wave-forced ADCIRC model, which is entirely 2D. The longshore velocity profiles, in general, are wider from SC than from ADCIRC. Additionally, because of the roller transition in the SC model, the location of maximum V(x) is usually further upslope than that from the ADCIRC model, even though the wave forcing is identical. Further tests against field data, as well as the NSSM (Navy Standard Surf Model), are forthcoming.

Comparison with DELILAH and other (later) field data. Preliminary comparisons of the SC model against DELILAH data (all cases) indicate promising performance. As of yet, no detailed analyses has been done of the resulting comparisons - however, it is believed that offshore conditions with significant spectral width (more random) likely leads to poorer comparisons than those conditions which are more narrow-banded. This is plausible, since the wave driver in SC is the monochromatic REFDIF1, and random wave conditions were represented by a representative monochromatic wave. Additionally, it is also believed that higher wave conditions also lead to poorer comparisons. This is probably because nonlinearity becomes more important in the wave train, and the linear REFDIF1 model is incapable of capturing this nonlinearity. More detailed analysis will follow, as well as comparison to Duck94 and SandyDuck data.

Parallel version of the computer code. A parallel version of the SC model is presently being developed and tested on a Linux cluster - this is the ultimate target platform, as the UDel ORCA system is similar. Open MP is being used, and some code optimization outside of parallelization is also being undertaken.

Data assimilation. In contrast to the approach of Feddersen (in which a fairly simple hydrodynamic model is being augmented with a sophisticated assimilation scheme), we endeavor to couple the sophisticated SC model with a straightforward data assimilation scheme: nonlinear least squares. Prior to assimilation, a sensitivity analysis is being performed. This analysis reveals that estimation of the bottom friction has the greatest effect on the results, far more than estimates of any other free parameter in the model. However, the sensitivity analysis also reveals that all free parameters are estimatable, and that no one parameter will have an unduly large effect on the estimation of all parameters. We will then use this information to design a successful data assimilation scheme.

RESULTS

The manual of approximately 50 pages is primarily an introduction to how to use the model system. It gives a brief description of the theoretical background for the model and its various features such as short wave forcing, bottom friction, turbulence modelling, numerical scheme etc. A section describes capabilities and limitations of the model system, and about 60\% of the manual is a direct user guide. Finally a sample computation is described in detail both in terms of input and in terms of discussion of the physical features shown in the output.

In the investigation of boundary errors it was found that at the inflow (upstream) boundary the error decays exponentially as we move downstream from the boundary. The decay rate is proportional to the

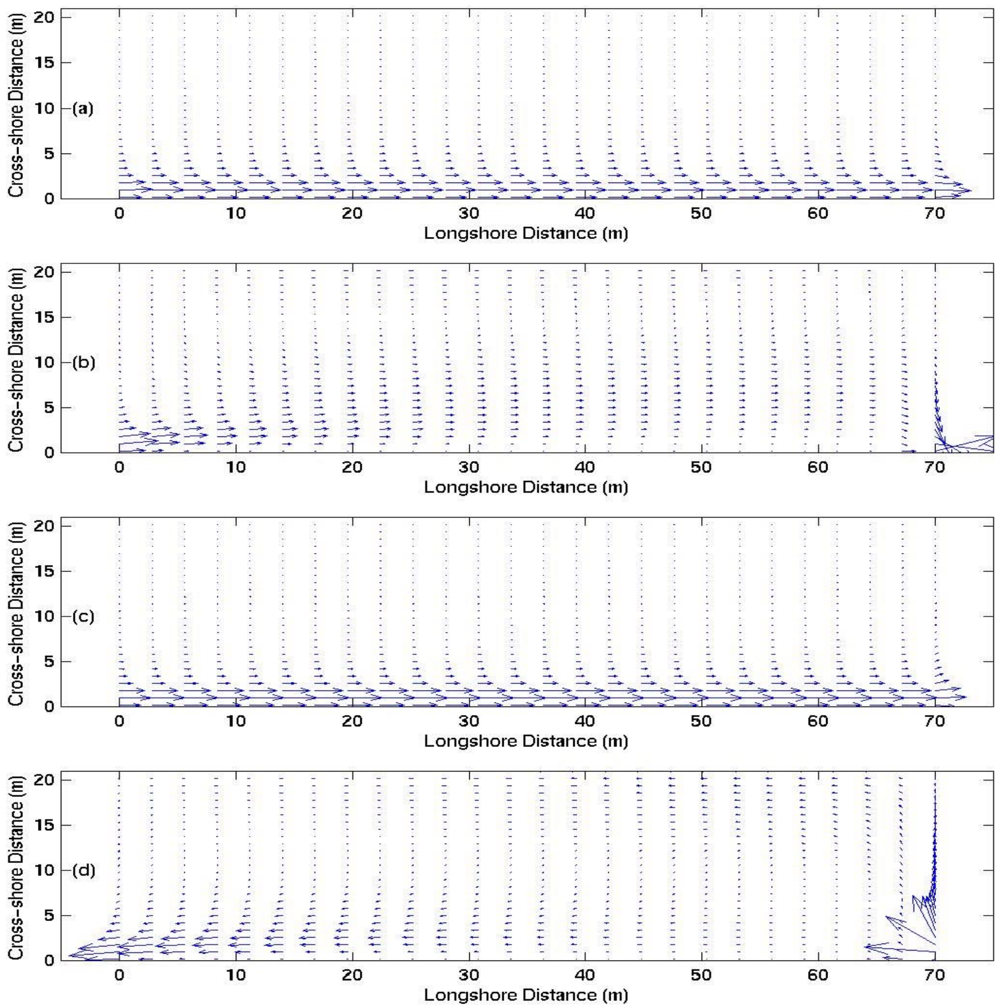

Figure 1. The effect of errors in the specified cross-shore boundary conditions. a) and c) show total velocity b) and d) the deviation in the velocity field (magnified 20 times relative to the total velocity) resulting from specifying a boundary flux 10% too large ((a) and b)) and a flux 10% too small (c) and d)). The error is not discernible in the total velocities. However, the figure shows that in both cases the errors in the velocity decrease to a fraction of the boundary errors a short distance into the computational domain, though they spread further downstream when the flux is over-estimated (b) than when it is under-estimated (d).

bottom friction, but inversely proportional to the depth. This implies a relatively large region into the computational domain would be affected by such errors, though decreasingly so the closer we are to the shoreline.

Around the down stream boundary errors in the volume flux specified turn out to be very local and resembles the outflow from a sink or bathtub. Thus the downstream end of a computational domain is only affected at the region within a few water depths from the boundary.

Fig 1 shows both the total velocity and the error in the velocity field for two cases: one with over-estimation, one with under-estimation of the boundary volume flux. The figure illustrates the result that the spreading and decay of the errors follow different patterns depending on whether we over-predict or under-predict the volume flux along the boundaries. Under-predicting the volume flux gives better results. This is being investigated further.

The results of the work done will contribute to the reliability of the model and help bringing it to use in practical cases such as planning of naval operations.

TRANSITIONS

The SC-model is a central element in the planned community model under development in the NOPP project "Development and verification of a comprehensive community model for physical processes in the nearshore ocean". Within that project the model-system has been passed on to several people. Thus Dr Dan Hanes, University of Florida, Gainesville, Dr Tom Drake, North Carolina State, University, and Dr. Tuba Özkan-Haller, University of Michigan, all members of the NOPP-group of PI's, have requested and received a copy of the code as well as the manual, and contacts about updates toward the reference version now available have been maintained. In addition Dr Daniel Conley, University of New York at Stoney Brook as well as Dr Jane Smith at WES have requested and received code and manual.

RELATED PROJECTS

"The generation of rip currents and circulation around coastal structures" (Sponsor: NOAA, Sea Grant
"Surf and surf zone hydrodynamics" PI: Peregrine, CoPI: Svendsen (Sponsor: ONR NICOP)
"Development and verification of a comprehensive community model for physical processes in the nearshore ocean". PI's Kirby, Svendsen, (at UD, and others outside UD)(Sponsor: NOPP)
"A computational model for the hydrodynamical and littoral processes at the large-scale sediment transport facility at WES" PI: Svendsen (Sponsor: ARO)

PUBLICATIONS

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